RESEARCH PROPOSAL

"A Study on Fuzzy Multi-Objective Transportation Problem using Goal Programming"

A synopsis submitted to

SWAMI RAMANAND TEERTH MARATHWADA UNIVERSITY, NANDED, MAHARASTRA, INDIA

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Submitted By

Mr. Rathod Savan Bhaurao
M.Sc. (Statistics)
Phone No: 9420445903
Email ID: savanrathod2412@gmail.com

Under the Guidance of

Dr. Madhav Ramrao Fegade
Assistant Professor & Head,
Department of Statistics,
Digambarrao Bindu Arts, Commerce
and Science College Bhokar, Dist:Nanded
431801. (M.S.) INDIA.
Email Id: mrfegade@gmail.com
Phone No:-9922675834

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1. Introduction

Operations Research (O.R.) is a multidisciplinary branch and its origin in World War II and afterwards it became very popular throughout the world. O.R. is successfully used not only in military affairs but also in industry, government and business. India is one of the first few countries of the world who started using O.R. Defining O.R. is a difficult task as its boundaries and content are not yet fixed. O.R. can be regarded as use of mathematical and quantitative, techniques to substantiate the decision being taken. O.R. takes tools from subjects like mathematics, statistics, engineering, economics, psychology etc. and uses them to score the consequences of possible alternative actions. Today it has become a professional discipline that deals with the application of scientific methods to decision making-especially to the allocation of scarce resources.

Developing appropriate mathematical models for situations, processes, systems or environment is basic essence of O.R. study. The model then can be tested, and operated on to determine the effects of changing the values of variables with particular reference to optimization of some criterion. Linear programming, non-linear programming, dynamic programming, game theory, Markov process, waiting line theory and simulation are some of the models and techniques that are used in O.R. There is role for O.R. in almost all areas of business decisions.

O.R. has certain limitations also. These limitations are mostly related to the problems of model building and time and money factor involved in its applications rather than its practical utility. Magnitude of computation ‘involved, lack of consideration for non-quantifiable factors and psychological issues involved in implementation are some of the limitations of O.R. Specialists in O.R. are not the decision makers themselves; they only provide rational basis for decision making to executives. There is a gap between who provides a solution and who wishes to use it. Due to this gap, management sometimes offers resistance to the use of O.R. The gap between O.R. scientists and managers is diminishing fast. O.R. techniques are gaining acceptance and respect day-by-day as they improve manager’s decision making effectiveness.

O. R. is an analytical method of problem-solving and decision-making that is useful in the management of organizations. The research problems are broken down into basic components and then solved in defined steps by mathematical analysis. It provides a more powerful approach to decision making than ordinary software and data analytics tools. It can be helpful to companies to achieve more complete datasets, all available options, to predict all possible outcomes and to estimate risk. Additionally, operations research can be tailored to specific business processes or use cases to determine which techniques are most appropriate to solve the problem.

Hitchock [8] proposed standard form of the transportation model along with a solution procedure. He considered the problem of minimizing the cost of distribution of product from several factories to a number of customers. Koopmans [10] took the leading role in bringing to the attention of economists, the potentialities of the linear programming models. The rapid development of the economic theory of such models was due to the insight gained by the researchers during the world war-II with a special class of linear programming models called transportation model. The problem is called transportation problem because it involves the transportation of goods from several sources to a number of destinations. Dantzig [6, 7] formulated the transportation problem as a special class of

linear programming problem and then developed a special form of simplex technique, taking advantage of the special nature of the coefficient matrix and involving hundreds of equations in thousands of unknown variables. Transportation problem can be broadly classified into two major categories, namely, single-objective and multi-objective transportation problem.

- **Transportation Problem:**

Let us consider that there are m sources and n destinations. Let x_{ij} be the amount to be shipped from source i to destination j, $1 \le i \le m, 1 \le j \le n$. x_{ij} will be an integer greater than, or equal to, zero. Also let a_i be the amount of supply at source $i = 1, \dots, m$ and b_j the demand at destination $j = 1, \dots, n$. The unit Transportation cost from source i, to destination j is c_{ij}, $1 \le i \le m, 1 \le j \le n$.
The transportation problem linear programming from with the inequality constrains Therefore,
Case I:-

$$Minimize\ Z = \sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}\, x_{ij} \qquad ..(1)$$

subject to

$$\sum_{i=1}^{m} x_{ij} \ge b_j, \qquad j = 1,2,3, \dots, n \qquad ..(2)$$

and

$$\sum_{j=1}^{n} x_{ij} \le a_j, \qquad i = 1,2,3, \dots, m \qquad ..(3)$$

where $x_{ij} \ge 0\ and\ x_{ij}$ integer.

For the model to be feasible we must have the total supply is at least equal to the total demand

$$\sum_{i=1}^{m} a_i \ge \sum_{j=1}^{n} b_j$$

Case II: Single objective Transportation Problem with equality constraints [ ]

A single objective transportation problem is represented as:

$$Min\ Z = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij} \qquad ..(4)$$

Subject to,

$$\sum_{i=1}^{m} x_{ij} = a_i, \qquad i = 1,2,\dots,m \qquad \dots(5)$$

and

$$\sum_{i=1}^{m} x_{ij} = b_j, \qquad j = 1,2,\dots,n \qquad \dots(6)$$

$$x_{ij} > 0, i = 1,2,\dots,m\ , j = 1,2,\dots,n$$

But in real world transportation problem, input data or related parameters are often imprecise / fuzzy owing to incomplete or unobtainable information

- **Multi-objective Transportation problem (MOTP)**

In decision making problems there often exist several non commensurable criteria, which must be considered. This situation is formulated as a multi-criterion optimization Consider m origins (or sources) O_i ($i = 1,\dots,m$) and n destination D_j ($j = 1,\dots,n$) At each origin O_i, Let a_i be the amount of a homogeneous product which we want to transport to n destinations D_i to satisfy the demand for b_j units of the product there. A penalty c_{ij}^{p} is associated with transportation of a unit of the product from i^{th} source to j^{th} destination corresponding to the z^{th} penalty criterion. The penalty could represent transportation cost; delivery time, quantity of goods delivered, under-used capacity, etc. A variable x_{ij} represents the unknown quantity to be transported from origin O_i to destination D_j. A multi-objective transportation problem can be represented as:

$$Minimize\ Z = \sum_{i=1}^{m}\sum_{j=1}^{n} C^{p}{}_{ij}\, x_{ij}, \quad p = 1,2,\dots,P \qquad \dots(7)$$

Subject to

$$\sum_{j=1}^{n} X_{ij} = a_i\ , \quad i = 1,2,\dots,m \qquad \dots(8)$$

and

$$\sum_{i=1}^{m} X_{ij} = b_j\ , \quad j = 1,2,\dots,n \qquad \dots(9)$$

$$X_{ij} \geq 0 \text{ for all } i,j$$

Where the subscript on Z_p and superscript on c_{ij}^{p} denote the p^{th} penalty criterion; $a_i \geq 0$ for all $i, b_j \geq 0$, for all $i,j,c_{ij}^{p} \geq 0$ for all i,j, and p

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j \ (Balanced\ condition)$$

The balanced condition is treated as a necessary and sufficient condition for the existence of a feasible solution to the balanced linear transportation problem. A standard transportation problem has exactly $(m + n)$ constraints and $(m \times n)$ variables.

- **Fuzzy programming :** [26]

In the real-life uncertain situations, the fuzzy set theory is an important topic to the interested readers. Although the fuzzy set theory is used in the field of operations research as a tool for solving multi-objective optimization problem, here, we intend to use fuzzy approach for accommodating real-life situations in multi-objective transportation problem through the fuzzy parameters.

Definition: (Fuzzy set)

A fuzzy set $\tilde{A}$ is a pair $(A, \mu_{\tilde{A}})$ where A is a crisp set belongs to the universal set X and $\mu_{\tilde{A}} : X \to [0,1]$ is a function, called membership function.

- **Fuzzy Multi-Objective Transportation Problem (FMOTP):**[2]

FMOTP is a special type of multi-objective linear programming problem in which some of the parameters are represented in terms of fuzzy numbers. Suppose that m sources contain different amounts of a commodity which must be distributed into n destinations. Associated with each link (i, j) from source i to destination j, there are h fuzzy attributes $\tilde{c}_{ij}^{k}(k = 1 \ldots, h)$ for transportation. The problem is to determine a feasible shipping plan from sources to destinations in order to optimize the objective functions. Let s_i be the supply of the commodity at source i and d_j be the demand for the commodity at destination j. Then, the FMOTP with h fuzzy objectives can be formulated as the model, where x_{ij} represents the amount of commodity that is being transported from source i to destination j:

$$Optimize\ z = \left(\sum_{i=1}^{m} \sum_{j=1}^{n} \tilde{c}_{ij}^{1}\, x_{ij}, \ldots, \sum_{i=1}^{m} \sum_{j=1}^{n} \tilde{c}_{ij}^{h}\, x_{ij} \right) \qquad ..(10)$$

Subject to,

$$\sum_{j=1}^{n} x_{ij} = s_i, \qquad i = 1, \ldots, m, \qquad ..(11)$$

and

$$\sum_{i=1}^{m} x_{ij} = d_j, \qquad j = 1, \ldots, n, \qquad ..(12)$$

$$x_{ij} \geq 0, \qquad i = 1, \ldots, m, j = 1, \ldots, n.$$

Note that the best possible solution for FMOTP would be the ideal solution $\tilde{f} = (\tilde{f}_1^*, \tilde{f}_2^*, \dots, \tilde{f}_h^*)$ given by:

$$\tilde{f}_k^* = Optimize \sum_{i=1}^{m}\sum_{j=1}^{n} \tilde{c}_{ij}^k x_{ij} \quad ..(13)$$

$$\sum_{j=1}^{n} x_{ij} = s_i, \qquad i = 1, \dots, m \quad ..(14)$$

$$\sum_{i=1}^{m} x_{ij} = d_j, \qquad j = 1, \dots, n \quad ..(15)$$

$$x_{ij} \geq 0, \qquad i = 1,2, \dots, m, j = 1, \dots, n.$$

As the objective functions of FMOTP are conflicting, it is impossible to obtain the ideal values. In this case, distance between a feasible solution in the objective space and the ideal solution can be minimized with the aim of seeking a solution as close as possible to the ideal solution for each choice of a norm. In this case, we use the following weighted compromise programming problems based on ℓ_1 norm and ℓ_2 norm:

$$Min \sum_{k=1}^{h} w_k \left| \sum_{i=1}^{m}\sum_{j=1}^{n} \tilde{c}_{ij}^k x_{ij} - \tilde{f}_k^* \right| \quad ..(16)$$

Subject to

$$\sum_{j=1}^{n} x_{ij} = s_i, \qquad i = 1, \dots, m \quad ..(17)$$

and

$$\sum_{i=1}^{m} x_{ij} = d_j, \qquad j = 1, \dots, n \quad ..(18)$$

- **Goal Programming Approach**

Goal programming (GP) is one of the most efficient techniques for solving multi-objective optimization problems. It is used as a powerful tool which draws upon the highly developed and tested techniques of linear programming and at the same time provides a simultaneous solution to the complex system of competing objectives and it has been widely accepted and applied technique mainly because of its underlying philosophy of satisfiable. Goal programming has been applied in diverse fields and is an excellent model in a wide variety of real-world problems, which have multiple objectives. In general terms GP minimizes undesired deviations from target values. It is a special compromise multi-criteria method assuming that decision maker known goals values and their relative importance. It may be designed to consider many goals simultaneously when searching for compromise solution and it is supported by mathematical programming.[16]

The basic approach of goal programming is to set up a specific numeric goal G_k for each objective function $F_k(x)$. Then the total deviation from the specified goal $\sum_{k=1}^{K}|d_k|$ is minimized, where d_k is the deviation from the goal G_k for the k^{th} objective function. For

formulating the absolute values, d_k can split into positive and negative parts such that

$$d_k = d_k^+ - d_k^-, \ \ with \ \ d_k^+ \geq 0 \ and \ d_k^+ . d_k^- = 0 \ .$$

Hence, $|d_k| = d_k^+ - d_k^-$ these negative deviation d_k^- and positive deviation d_k^+ are known as under-achievement and over achievement, respectively, where achievement implies that the goal has been achieved. A typical GP is expressed as follows: [16]

$$Min \sum_{k=1}^{K} (d_k^+ + d_k^-) \qquad ..(19)$$

Subject to,

$$F_k(x) + d_k^+ - d_k^- = G_k, \qquad k = 1,2, \dots, K \qquad ..(20)$$

$$\sum_{j=1}^{n} x_{ij} = \ a_i \qquad i = 1,2, \dots, m \qquad ..(21)$$

and

$$\sum_{i=1}^{m} x_{ij} = \ b_j \qquad j = 1,2, \dots, n \qquad ..(22)$$

$$x_{ij} \geq 0 \quad \forall j = 1,2, \dots, n, k = 1,2, \dots, K$$

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j \qquad ..(23)$$

$$a_i > 0, b_j > 0, c_{ij}^k > 0, x_{ij} \geq 0 \ \forall \ i, j,$$

$$k = 1,2, \dots, K. \ \ d_k^+, d_k^- \geq 0, \qquad k = 1,2, \dots, K$$

where $d_k^- \geq 0, d_k^+ \geq 0$are, respectively under- and over-derivations of k^{th} goal.

2. Review of Literature and Development in the subject.

Venkatasubbaiah et al.[23] proposes membership functions and goal deviation functions from Pareto solutions for each objective, and these functions are added as constraints. By introducing a max-min operator λ is an auxiliary variable, then the equivalent fuzzy interactive goal programming problem is formulated to maximize λ and the solution is obtained by using LINGO software. Khan et al. [9] review of the connection between modern era techniques & fuzzy multi objective optimization (FMOO) to deal with its shortcoming and FMOO used in transportation problem. Multi objective optimization represents an interest area of research since most real life problem have a set of conflict objectives. MOO has its root in late nineteenth century welfare economics, in the works of Edge worth & Pareto. But due to some shortcoming faces, researchers attract to FMOO and they use modern era technique like artificial intelligence. They have developed a fuzzy linear programming method for solving the transportation problem with fuzzy goals, available supply & forecast demand and showing a frame for (FMOTP) solution.

Rivaz et al.[19] focus is on fuzzy goal programming to solve multi-objective transportation problems. A new model based on fuzzy goal programming is presented. It

could be proved that at least a weakly efficient solution is obtained for the multi-objective transportation problem by solving the new model. Further, an efficient solution is achieved if the new model has a unique optimal solution.

Redi et al.[17]optimal water allocation modeling under conflicting demand and supply, from the decentralized production, consumption and water allocation planning for agricultural, industrial and domestic sectors a new methodology is proposed to coordinate the production and consumption of finished products that would lead to better water management. The problem is modeled as a Two-Stage Production Dynamic Inventory Control Optimization (TSPDICO) problem that considers the multi-stage decision problem as several sub problems of two-stage model application and in subsequent steps the algorithm modifies the previous solutions by fixing values obtained at current iteration until finally only one two-stage problem remains in the optimization problem. Thus, the proposed (TSP-DICO) incorporates inventory control models to water allocation planning methodology they developed a water management decision to avoid conflicts. Li et al.[11] propose a new fuzzy compromise programming approach to multi-objective transportation problems. It is shown that the approach proposed can give a compromise solution that is not only non-dominated but also optimal in a certain sense. The proposed approach is robust enough to cover a wide spectrum of methods. Zimmermann's [26] fuzzy programming approach is essentially equivalent to one of the proposed method's special cases.

Bhargava et al.[3] to develop a fuzzy goal programming model in order to satisfy the customers' demands to the fullest of a SME company producing frozen foods considering majorly three objectives. These are achieving the total distribution of five products of frozen foods to three different locations, maximizing total profits and minimizing the total manufacturing costs using LINDO 11.0 as the optimizer solver. The distribution of all five products of frozen foods is satisfied at Ampang and Kaula Lumpur and not in Kulai for two products. Achieving a satisfactory profit level with the linear membership function, $\boldsymbol{\mu_{16}}$ representing imprecise nature of this goal are achieved partially. The number of goals to be considered can also be increased based on the desirability of the decision maker in relation to their aspiration level.

Wahed et al.[1] solve the multi-objective transportation problem. The approach controls the search direction via updating both upper bounds and aspiration level of each objective function. The solution results provide a preferred compromise solution which is more realistic from the DM perspective. The approach is a powerful method to determine appropriate aspiration levels of the objective functions. The performance of the suggested approach was evaluated by using a set of metric distance functions with respect to the two previously developed methods. The combination of goal programming, fuzzy programming, and interactive programming in one methodology is a powerful tool for solving MOTP and FMOTP.

Singh et al.[21] developed to solve the multi-objective transportation problem. The approach controls the search direction via updating both upper bounds and aspiration level of each objective function. The solution results provide a preferred compromise solution which is more realistic from the DM perspective. The approach is a powerful method to determine appropriate aspiration levels of the objective functions. The performance of the suggested approach was evaluated by using a set of metric distance functions with respect to the two previously developed methods. The combination of goal programming, fuzzy programming, and interactive programming in one methodology is a powerful tool for solving MOTP and other multi-objective optimization problems.

Azzabi et al. [13] presented a road accident constraint in which data of three networks are fuzzy values and the objective function assumes multiple objectives. Then, non-linear constraints are liberalized by defining and adding auxiliary constraints. Finally,

the optimal solution of the problem is founded by solving the linear programming problem with fuzzy and crisp constraints and applying fuzzy programming technique. Various fuzzy approaches have been proposed for the solution of multi-objective linear plus linear fractional programs problem and most of the approaches have min trial computational burden. They approach is to give simple procedure for the solution of multi-objective fuzzy goal programming problems**.**

Maity et al.[14] proposed research work, transportation cost, supply and demand parameters are considered as triangular fuzzy numbers. Thereafter, a two-step method is proposed for solving the FTP. In the first step, fuzzy arithmetic is introduced to convert FTP into a linear programming problem with fuzzy costs and crisp constraints. The second step is presented a new decomposition procedure to convert the resulting problem into crisp valued bounded transportation problems and solving these, they obtained the optimum solution. Again, the study presents a method for solving the transportation problem (TP) with fuzzy parameters. In the usual TP, it is always seen that the amount of goods transported to the destinations also tends to a minimum value which produces the minimum transportation cost.

3. Objectives of the Research

Some of the proposed aims and objectives of the research study are:

- To study of the fuzzy theory and its application
- To study of goal programming approach associated with TP.
- To study FMOTP using Goal Programming
- To apply scientific tools to solve FMOTP and Goal Programming
- Attempt to investigate some properties of the solutions existence, uniqueness and other of FMOTP and Goal Programming
- To apply and develop method the FMOTP using Goal Programming analysis to the various fields of day to day life, Business and Technology.

During the period of research many new objectives may be developed which will be beneficial for the society.

4. Methodology:

- Collection of relevant literature from good libraries in India and abroad.
- Study to obtain fuzzy multi-objective transportation problem with existing method
- To develop Statistical model FMOTP using goal programming
- To develop a new algorithm to FMOTP using goal programming
- Consultations with expertise on topic relevant to proposed work
- Use of LINGO or any scientific tool available for the solution fuzzy multi-objective transportation problem consultations with expertise on topics relevant to proposed work.
- Publishing original work.

5. Importance of Study/Society application:

The present research work proposes our main focus is to study and apply the optimization techniques for the determination of the solution of fuzzy multi-objective transportation problem using goal programming. In real life we may face many complex

equations while constructing the transportation problem and goal programming problem. Use of (LINDO or any) other scientific tool will provide an easy access for such complex equation and can generate approximate solutions.

- **National and International Status and some diversified applications of Machine learning:**

Zangiabadi et al.[25] proposed fuzzy goal programming technique, decision maker can obtain a satisfying solution. Also the decision maker is able to analyze the aspiration levels. In the present work, the equivalence between fuzzy goal programming and fuzzy programming for solving MOTP is studied. A special type of nonlinear (hyperbolic) membership function is used and a nonlinear optimization model is developed to solve MOTP, which can be solved by using one of the available software. The method can be easily implemented to solve any linear multi-objective programming problem. Singh et al.[22] proposed solution procedure for multi-objective stochastic STP is presented where the parameters like supplies, demands and conveyance capacities are considered as gamma or Erlang distribution. Chance-constraint programming technique is used to establish the equivalent deterministic model of the problem. the deterministic model becomes nonlinear, whereas the deterministic model remains linear for distributions like uniform or exponential or normal. Since random variables are present in the problem, it is not possible to apply the initial feasible condition. For the considered problem the feasibility conditions are obtained using chance-constraint technique.

Pramanik et al.[16] extend the concept for solving QBLPP. The first construct quadratic membership function by determining individual best solution of the objective function of the level DMs. The quadratic membership functions are then transformed into linear membership functions by first order Taylor series approximation. Since the objectives of the level DMs are generally conflicting in nature, possible relaxations of decision of upper and lower level DMs are simultaneously considered for avoiding decision deadlock in the decision-making situation by providing preference bounds on the decision variables under their control. Then FGP models are formulated for achieving highest degree of each of the membership goals by minimizing negative deviational variables. To demonstrate the efficiency of the proposed FGP approach, three numerical examples are solved and distance function is used to select compromise optimal solution.

Revathi et al.[18] investigated a four dimensional multi-level multi objective multi item fractional transportation problem under uncertain environment. Four dimensional multi-level multi-objective multi-item fractional transportation problem to handle real life situations has been studied for the first time ever they have solved the transportation problem taken using fractional programming instead of linear programming as the ratio to be optimized in fractional programming often describes the efficiency of the system considered. The problem has been converted into equivalent deterministic problem using expected value method and chance constrained method. The compromise solution has then been obtained for hierarchical decision making system suitably to avoid dead locks in situations involving conflicting objectives, using goal programming method

- **Significance of the study**

The aim of this work to study the optimization technique's for the solution of the transportation problem. For solving the transportation problem we introduced fuzzy transportation problem and apply the scientific tools (like LINGO or others) for the solution. The proposed method attempts to minimize the total production and

transportation costs and the total delivery time with reference to available supply and machine capacities at each source, as well as forecast demand and warehouse space constraints at each destination. Here we try industrial case to demonstrate the feasibility of applying to a real transportation planning decision problem. In real world transportation planning, decision problems, input data and related parameters, such as available supply and forecast demand, are often imprecise/fuzzy because some information is incomplete or unobtainable. Also, the decision maker must simultaneously handle conflicting goals that govern the use of the constrained resources within organizations.

6. Proposed work Plan/ Formulation and Structure of Study: Year-wise Plan of work and targets to be achieved

Sr. No	Period	Plan of the Work
1	**First Year**	1. To collect and study of review of literature of fuzzy multi-objective transportation problem and goal programming.
		2. To find the solution of the fuzzy multi-objective transportation problem using goal programming and introduction of fuzzy multi-objective transportation problem.
2	**Second Year**	1. To apply the scientific tool for the fuzzy multi-objective transportation problem using goal programming.
		2. To develop new model for fuzzy multi-objective transportation problem using goal programming.
		3. To solve the fuzzy multi-objective transportation problem using goal programming using different methods and compare results.
3	**Third Year**	1. The publication of the findings of the research.
		2. Publication of papers in various national and international journals & conferences.
		3. Thesis writing.

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Signature

Research Scholar
Mr. Rathod Savan Bhaurao

Signature

Research Guide
Dr. Madhav Ramrao Fegade